Removal of phosphate from a river

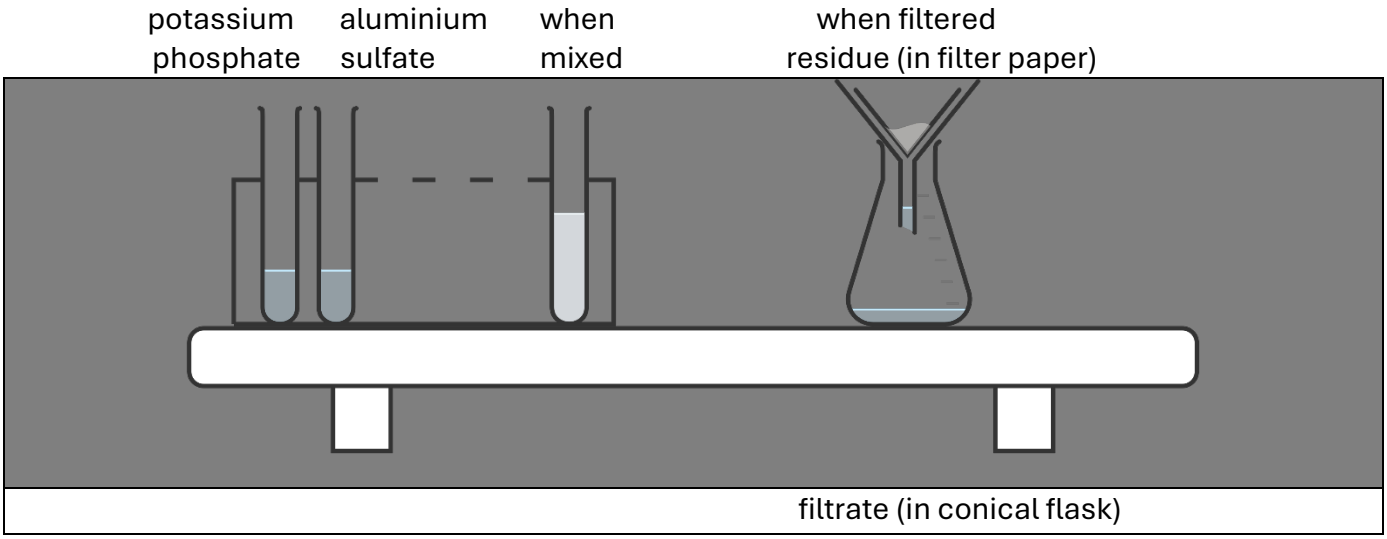
Phosphate pollution causes eutrophication, harming rivers and aquatic life. It can enter rivers through fertiliser runoff from farms.

Alum (short for aluminium sulfate), with the formula $Al_2(SO_4)_3$ is a chemical that can be added to contaminated water to remove phosphate pollution.

A student modelled phosphate removal in the laboratory. They mixed together solutions of potassium phosphate and aluminium sulfate. A cloudy white mixture was formed. Filtering the mixture produced a white residue and a colourless filtrate.

potassium phosphate(aq) + aluminium sulfate(aq) → potassium sulfate (aq) + aluminium phosphate(s)

$$2K_3PO_4(aq) + Al_2(SO_4)_3(aq) \rightarrow 3K_2SO_4(aq) + 2AlPO_4(s)$$



When the student added a few more drops of aluminium sulfate solution to the filtrate, they observed some additional white solid formed.

The reaction is a precipitation reaction as it matches the format of:

soluble ionic compound + soluble ionic compound → insoluble ionic compound + soluble ionic compound

When potassium phosphate is removed from a river by the addition of aluminium sulfate, the same four ions of potassium, phosphate, aluminium and sulfate are present in both the reactants and products. The ions have been recombined into new arrangements, but as no ions have been lost the mass remains unchanged. This is the conservation of mass.

E.g. in the balanced equation $2K_3PO_4 + Al_2(SO_4)_3 \rightarrow 3K_2SO_4 + 2AlPO_4$ the total number of atoms before reaction are 6 x K, 2 x P, 2 x Al and 20 x O, which are the same numbers of each after the reaction is complete, so mass is conserved.

When the two solutions are mixed there are two new possible combinations of cations and anions – potassium with sulfate and aluminium with phosphate.

Potassium sulfate is soluble, but aluminium phosphate is white and insoluble, so a solid forms which is observed. It is a precipitation reaction because when the two solutions are mixed a (white) solid precipitate forms because the ionic product, aluminium phosphate, is insoluble. In this case the aluminium phosphate can be filtered out of the solution. The filtrate (solution) contains the soluble potassium sulfate.

In the student experiment, more precipitate was made when additional aluminium sulfate was added to the filtrate which shows that some unreacted potassium sulfate was present in this filtrate.

If aluminium sulfate (alum) is being added to a polluted water sample to remove <u>all</u> the dissolved phosphate, enough must be added. If not enough alum is added in the first instance, then not all of the phosphate would be removed by precipitation and filtration and the remaining excess phosphate in the water would have negative effects on the environment e.g. algal bloom.